Template for ISB Documentation of Stressors

A. General Information: Multiple Stressors - Interactions

1. Name or Location of Example/Approach: meta-analysis of stressor effects on marine and coastal ecosystems

2. Literature/Citations Used: Crain et al. (2008) Interactive and cumulative effects of multiple human stressors in marine systems. Ecology Letters 11: 1304-1315. Doi:10.1111/j.1461-0248.2008.01253.x

3. Reviewer(s): Elizabeth Canuel

B. Specific Questions:

1. What stressors are considered?

Salinity, sedimentation, nutrients, toxins, fishing, sea level rise, temperature, CO2, UV, invasives, disease, hypoxia, disturbance.

Interactions between multiple stressors

2. Are stressors categorized? If so, how?

Interactions categorized as additive (26%) synergistic (36%) and antagonistic (38%).

Interaction type varied by response level (community: antagonistic, population: synergistic), trophic level (autotrophs: antagonistic; heterotrophs: synergistic), and specific stressor pair (seven pairs additive; three pairs synergistic; three pairs antagonistic).

3. Are the relations between stressors and management objectives modeled, and if so, how?

4. If stressors are prioritized, describe the general approach.

Variation in multiple stressor effects shows that context matters. In two-thirds of the studies, differences in context changed stressor interaction effect sizes significantly and changed interaction classification to more negative type. For example, number of synergistic interactions doubled in ambient vs, increased levels of third stressor. As number of stressors increased, stressor pair interactions become more complex and more synergistic.

5. How might this approach be relevant to Bay Delta?

Results from this study indicate need to account for stressor interactions in ecological studies and conservation planning. Since multiple stressors impact Delta ecosystem, more likely to be synergistic. Important to consider likelihood of synergistic effects between existing stressors when predicting effects of new stressors such as climate change.

6. Follow up regarding additional questions/literature review/etc?

Conducted Web of Science literature review of papers cited in Crain et al. and papers that have cited Crain et al. (2008).

Template for ISB Documentation of Stressors

A. General Information: Multiple Stressors - Interactions

1. Name or Location of Example/Approach: experimental simulations

2. Literature/Citations Used: Mora et al. (2007) PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES, 274 (1613): 1023-1028

3. Reviewer(s): Elizabeth Canuel

B. Specific Questions:

1. What stressors are considered? environmental warming, overexploitation and habitat fragmentation

2. Are stressors categorized? If so, how?

3. Are the relations between stressors and management objectives modeled, and if so, how?

4. If stressors are prioritized, describe the general approach.

5. How might this approach be relevant to Bay Delta?

Interaction between habitat fragmentation and harvesting generated an additive decline in population size. However, both of these threats reduced population resistance causing synergistic declines in populations also facing environmental warming. Declines in population size were up to 50 times faster when all threats acted together. These results indicate that species may be facing risks of extinction higher than those anticipated from single threat analyses and suggest that all threats should be mitigated simultaneously, if current biodiversity declines are to be reversed.

Results from this study highlight the importance of generation time in enhancing adaptation to selective forces and in explaining why some species have declined in step with global warming while others have not (e.g. Parmesan & Yohe 2003). These results provide evidence that species with long generation times are more prone to the effects of warming. The overall decline of populations facing any warming also highlights the sensitivity of ecological systems to increases in temperature (Poertner et al. 2001) and suggests that environmental heating itself is capable of causing negative effects on populations independent of other environmental factors that may change in relation to warming (e.g. rainfall, currents, productivity, etc.).

6. Follow up regarding additional questions/literature review/etc?

Template for ISB Documentation of Stressors

A. General Information: Multiple Stressors - Interactions

1. Name or Location of Example/Approach: whole ecosystem manipulation

2. Literature/Citations Used: Christensen et al. (2006) Multiple anthropogenic stressors cause ecological surprises in boreal lakes. Global Change Biology 12, 2316–2322, doi: 10.1111/j.1365-2486.2006.01257.x

3. Reviewer(s): Elizabeth Canuel

B. Specific Questions:

1. What stressors are considered? interactions between climate and acidification determine their cumulative impact on the food-web structure of coldwater lakes.

2. Are stressors categorized? If so, how?

Interactions among temperature, DOC, and pH were significant predictors of planktonic consumer and producer biomass in Lake 302S. Inclusion of interaction terms increased the predictability of additive models by 20.4% for consumers, and 14.4% for producers.

3. Are the relations between stressors and management objectives modeled, and if so, how?

Results highlight the prevalence and magnitude of interactions among anthropogenic stressors, and that their cumulative impact can generate ecological surprises in lakes. Other studies have similarly demonstrated the complex nonadditive impacts of multiple stressors in marine ecosystems (Hoffman et al., 2003; Przeslawski et al., 2005).

4. If stressors are prioritized, describe the general approach.

5. How might this approach be relevant to Bay Delta?

Interactions among warming, drought, and acidification, rather than the sum of their individual effects, best explained significant changes in planktonic consumer and producer biomass over a 23-year period. These stressors interactively exerted significant synergistic and antagonistic effects on consumers and producers, respectively.

6. Follow up regarding additional questions/literature review/etc?

Template for ISB Documentation of Stressors

A. General Information: Stressor Ranking

1. Name or Location of Example/Approach: Stressor Identification Guidance Document

2. Literature/Citations Used: U.S. Environmental Protection Agency, Office of Water

Washington, DC 20460, Office of Research and Development, Washington, DC 20460

EPA-822-B-00-025

3. Reviewer(s): Elizabeth Canuel

B. Specific Questions:

1. What stressors are considered? General approach but largely applied to water quality.

2. Are stressors categorized? If so, how?

US EPA document describes a process for identifying any type of stressor or combination of stressors that cause biological impairment. The Stressor Identification (SI) Guidance is intended to lead water resource managers through a formal and rigorous process that identifies stressors causing biological impairment in aquatic ecosystems, and provides a structure for organizing the scientific evidence supporting the conclusions.

Process: (1) Detect or suspect biological impairment, (2) List candidate causes, (3) Analyze Evidence, (4) Characterize causes, (5) Identify/apportion causes, (6) Management action.

3. Are the relations between stressors and management objectives modeled, and if so, how?

No models but the conclusions can be translated into management actions and the effectiveness of those management actions can be monitored.

4. If stressors are prioritized, describe the general approach.

EPA provides three methods for using evidence from multiple lines to characterize the cause of impairment. The process involves: (1) eliminating alternatives, (2) using

diagnostic protocols, and (3) weighing the strength of evidence supporting each candidate cause.

5. How might this approach be relevant to Bay Delta?

Application of this approach may be relevant to Bay/Delta. Several iterations may be needed in ecosystems with complex and/or multiple causes of impairment.

6. Follow up regarding additional questions/literature review/etc?

Template for ISB Documentation of Stressors

A. General Information: Stressor Ranking

1. Name or Location of Example/Approach: Multiple Lines of Evidence approach – sediment quality

2. Literature/Citations Used: Bay et al. (2007) Evaluating Consistency of Best Professional Judgment in the Application of a Multiple Lines of Evidence Sediment Quality Triad. Integrated Environmental Assessment and Management — Volume 3, Number 4—pp. 491–497

3. Reviewer(s): Elizabeth Canuel

B. Specific Questions:

1. What stressors are considered? Contaminated sediments – experts were asked to rank sites after being provided with sediment chemistry, sediment toxicity, and benthic infaunal community condition data for 25 sites.

2. Are stressors categorized? If so, how? No ranking

3. Are the relations between stressors and management objectives modeled, and if so, how?

Although the experts were highly correlated with respect to ordinal site rankings, considerable differences in how the experts rated the sites categorically were present.The significance of these results for making management decisions depends on the nature of the question. The effect on large-scale assessments in which the objective is to identify the worst locations or describe the relative condition of sites is likely to be small because there was good agreement among the experts in terms of overall condition classification and relative site ranking. The effect will be more significant with respect to making management decisions for specific sites, particularly those with intermediate levels of contamination, toxicity, or biological alteration, in that these sites could be variously classified as likely unimpacted (no remediation needed), inconclusive (more data needed), or likely impacted (potential remediation).

4. If stressors are prioritized, describe the general approach.

5. How might this approach be relevant to Bay Delta?

Several steps are recommended to reduce the uncertainty associated with the integration and interpretation of sediment quality triad data. First, key elements of the assessment strategy, such as the relative weight of each LOE, how multiple LOEs will be combined (e.g., scores, ranks, logic frameworks), and the criteria for determining the assessment conclusion should be determined during the design of the study. Second, comparability among studies can be improved by providing guidance on specific methods for measuring sediment chemistry (e.g., analyte list, detection limits, how sediment quality guidelines are used), sediment toxicity (e.g., test methods, toxicity classification thresholds), and benthic community condition (e.g., which metrics or indices to use, criteria for determining the effects). Finally, uncertainty in sediment quality assessment can be reduced through improved training of the individuals interpreting the data.

6. Follow up regarding additional questions/literature review/etc?